Nutrient Uptake and Partitioning in High-Yielding Corn

Crop Physiology

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Introduction:

- Nutrient uptake capabilities of hybrids with management practices in the 1940's through 1980's are well documented.
- Refined agronomic production practices (earlier planting dates, narrower row spacing, increased planting density) and the advent of transgenic insect protection may have changed the potential for season-long nutrient accumulation and utilization (Table 1).
- Current fertilizer recommendations based on older nutrient uptake data may not be adequate in supporting modern hybrids and management practices.

Research approach:

- Field experiments were conducted in 2010 at Champaign, Illinois on a Drummer-Flanagan silty clay loam and in DeKalb, Illinois on a Flanagan silt loam. Plots were planted in Champaign on May 24th and in DeKalb on May 20th to achieve a final stand of 84,000 plants ha^{-1} (34,000 plants ac^{-1}).
- One week before planting, 202 kg N ha^{-1} was applied as urea ammonium nitrate (28-0-0) with a sidedress application of 67 kg N ha^{-1} at V6 as weather-protected urea (46-0-0). At planting, 168 kg P_2O_5 ha^{-1} was applied as MicroEssentials® SZ™ (12-40-0-10S-1Zn) to mimic a fertilizer regime for a corn-soybean rotation (commonplace in Illinois, USA).
- All hybrids possessed herbicide tolerance and resistance to feeding from certain above-ground and below-ground insects:
  - DKC61-21 SSTX, 111 RM
  - DKC61-69 VT3, 111 RM
  - DKC63-42 VT3, 113 RM
  - DKC64-24 VT3, 114 RM
  - P33W84 HXX, 110 RM
  - H-9014 3000GT, 112 RM
- Six plants were sampled at each of six growth stages (V6, V10, V14, R2, R4, R6) for dry weight and nutrient analysis. Grain and stover samples were analyzed for N, P, K, Mg, S, Zn, B, Mn, Fe, and Cu concentration by A&L Great Lakes Laboratories (Fort Wayne, IN). Only N, P, K, S, and Zn are presented here.
- All values are expressed on a dry weight (0% moisture) basis. Figures were prepared in SigmaPlot using the simple spline option with smoothed data points.

Question: *What are the season-long mineral nutrition needs in contemporary corn production?*

Objective: *Quantify nutrient uptake and partitioning in commercial germplasm with transgenic insect protection grown under modern management practices.*

Current nutrient uptake capabilities:

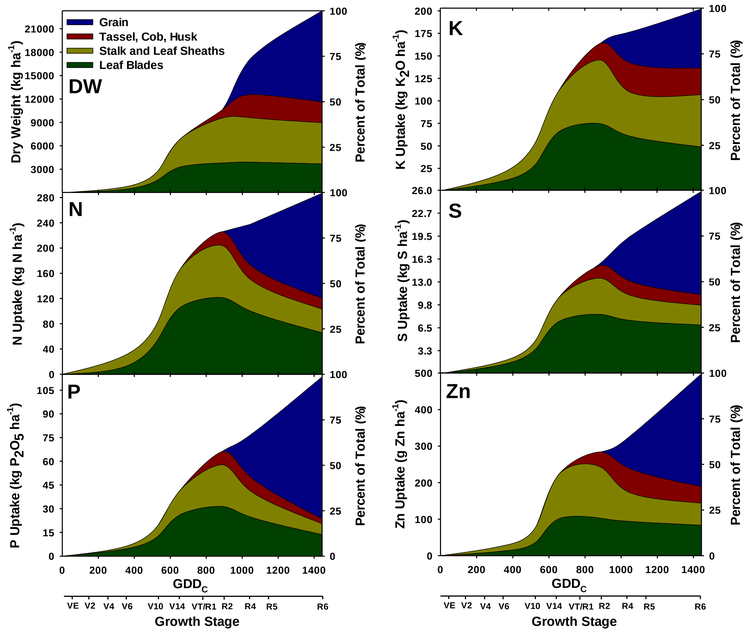

Figure 1. The seasonal accumulation and partitioning of dry weight (DW), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) averaged over six hybrids evaluated at two locations in 2010. The average grain yield of six hybrids was approximately 12.0 Mg ha^{-1}.

Table 2. Total macronutrient and micronutrient uptake and removal in Urbana and DeKalb, IL (2010). Harvest Index (HI) was calculated as the ratio between nutrient removed with grain and total nutrient uptake and is reported as a percent.

Nutrient	Total Nutrient Uptake		Nutrient Removal		Nutrient HI	
	Mean	Range	Mean	Range	Mean	Range
	kg ha^{-1}				%	
N	286	266 – 307	166	145 – 188	58	51 – 62
P_2O_5	114	100 – 133	90	73 – 108	79	70 – 82
K_2O	202	181 – 225	66	57 – 78	33	27 – 37
S	26	24 – 28	15	13 – 16	57	52 – 60
	g ha^{-1}				%	
Zn	498	448 – 563	308	269 – 353	62	60 – 65

- **Average grain yield and total biomass production were 12.0 and 23.2 Mg ha^{-1} respectively (Figure 1). Nutrients supplied in these quantities (Table 2) would be expected to meet corn requirements for this yield level.**
- **Location did not influence uptake of nutrients (data not shown) thus uptake patterns between locations were combined (Figure 1). Nutrient uptake at R6 was significantly different among hybrids (*P<0.05*, data not shown) and as a result, ranges of nutrient uptake are shown in Table 2.**
- **Nutrients with high total uptake (i.e. N, P, K) represent a yield limitation if not supplied in sufficient quantities. Those nutrients with greater HI values (e.g. N, P, S, Zn) are removed from a cropping system to a relatively greater extent.**
- **Our data (Table 2) suggest that total nutrient uptake has increased nearly two-fold compared to values reported by Hanway (1962b; see Table 1).**

Nutrient uptake timing:

- **As much as two-thirds of N and K uptake occurred before flowering compared to only one-half of P, S, and Zn (Table 3, Figure 1).**
- **Our data demonstrated greater post-flowering accumulation of P and K compared to Hanway (1962b) which may be due to longer relative maturity hybrids with greater dry matter production during late reproductive growth (e.g. R4-R6).**
- **Maximum rates of nutrient accumulation coincided with maximum rates of dry weight production, a 10-day period between V10 and V14 (Table 3). This period accounted for 20-30% of total uptake for all nutrients.**

Table 3. Rates of biomass and nutrient accumulation determined between the V10 and V14 growth stages and the percent of total nutrient uptake by R1 for measured parameters evaluated at two locations in Illinois during 2010. Rate of accumulation represents the maximum rate of nutrient uptake during the growing season.

Measurement	Rate of accumulation	Uptake by R1
	kg ha^{-1} day^{-1}	%
Biomass	439	35
N	8.9	65
P_2O_5	2.4	44
K_2O	5.8	63
S	0.7	48
	g ha^{-1} day^{-1}	%
Zn	14.2	48

Nutrient uptake - A look back:

Table 1. Agronomic management practices and measured total nutrient uptake in corn, compiled from select nutrient accumulation studies during the past 60 years. All units are expressed on a dry weight (0% moisture) basis. No fertility practice information was provided by Sayre (1948), although four differing fertility regimes were averaged from Hanway (1962a/1962b), and an irrigated, intensively fertilized and limed study was used by Karlen et al. (1988).

	Sayre, 1948	Hanway, 1962a/1962b†	Karlen et al., 1988
Agronomic parameters			
Row spacing, cm	107	107	30
Plant spacing, cm	36	66‡	30
Plant density, plants ha^{-1}	25,960	42,583	111,111
Productivity			
Grain yield, kg ha^{-1}	6,300	4,600	16,300
Biomass yield, kg ha^{-1}	13,700	13,600	31,800
Nutrient uptake			
N, kg ha^{-1}	159	141	386
P_2O_5, kg ha^{-1}	77	56	161
K_2O, kg ha^{-1}	131	87	446
S, kg ha^{-1}	-	-	40
Zn, g ha^{-1}	-	-	800

† Biomass and nutrient accumulation means averaged across four major fertility practices used by Hanway.
‡ Planted using a 'hill' system in which three seeds were placed in each cluster spaced 66-cm apart.

- **Previous literature demonstrates the range in nutrient uptake capabilities of hybrids and management practices common in the 1940's through the 1980's (Table 1).**
- **Although the biology of maize nutrient uptake and partitioning has likely not changed from earlier studies, increased grain yields and biomass production may be associated with greater total plant uptake and increased removal.**
- **These studies favored early season nutrient accumulation with an estimated 55% and 80% of P and K uptake occurring before flowering (Hanway, 1962b).**

Conclusions:

1. Are there key nutrients for high yield corn production?

✓ **Yes, nutrients with high requirements for production (N, P, K), or that have a high HI (P, Zn, S, N) allude to important nutrients for high yield.**

2. Can the agronomic management of nutrient application rate, placement, and timing in corn production be further improved?

✓ **Yes, accumulation of P, S, and Zn was greater during grain-fill than vegetative growth and as such, season-long supply of these nutrients are critical for optimum grain production. Application of fertilizers should meet plant needs during the greatest period of nutrient uptake, from V10 to V14.**

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